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IRRIGATION EXPERIMENTS WITH PRUNES

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IRRIGATION EXPERIMENTS WITH PRUNES[1]

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INTRODUCTION

THIS REPORT is one of a series on the water relations of fruit trees, and includes the measuring of certain responses of prune trees and fruit to different irrigation treatments in an orchard at Davis during 10 years, 1923 to 1933. The experiments described constituted a further inquiry into the question of whether measurable differences in plant responses are obtained with varying moisture contents between the field capacity and the permanent wilting percentage. Previous reports have dealt with peaches, prunes, and grapes.[(1, 2, 4)4] The experiments were conducted under interior valley conditions, with temperatures sometimes reaching 110° Fahrenheit in the summer, and 25° F in December and January. The annual rainfall for the 10 years averaged 14.7 inches. Under typical summer conditions, the evaporation from a standard class A United States Weather Bureau Station pan sometimes reached 0.5 inch per day; the daily loss from a standard white atmometer, sometimes 175 cc. Where water is available, irrigation of orchards in this region is generally practiced.

THE ORCHARD AND THE CULTURAL METHODS USED

The experimental orchard covers 3.2 acres. Planted in 1917 with carefully selected one-year-old nursery stock, it consists of 13 rows of 15 trees each of Agen (French) prune on myrobalan rootstock.

During the first six years, all trees were treated as nearly uniformly as possible. Pruning, during the first few years, was essentially a training process, designed to provide a strong system of framework branches. Thereafter it consisted of a light annual thinning, to prevent crowding of branches in later years. Throughout, the pruning has been relatively light, with no innovations that might change the bearing or growth habits. After the preliminary training period, the trees assumed their natural shape. Figures 1 and 2 show a typical tree at successive stages of growth.

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4 Superscript numbers in parentheses refer to "Literature Cited" at the back of the bulletin.

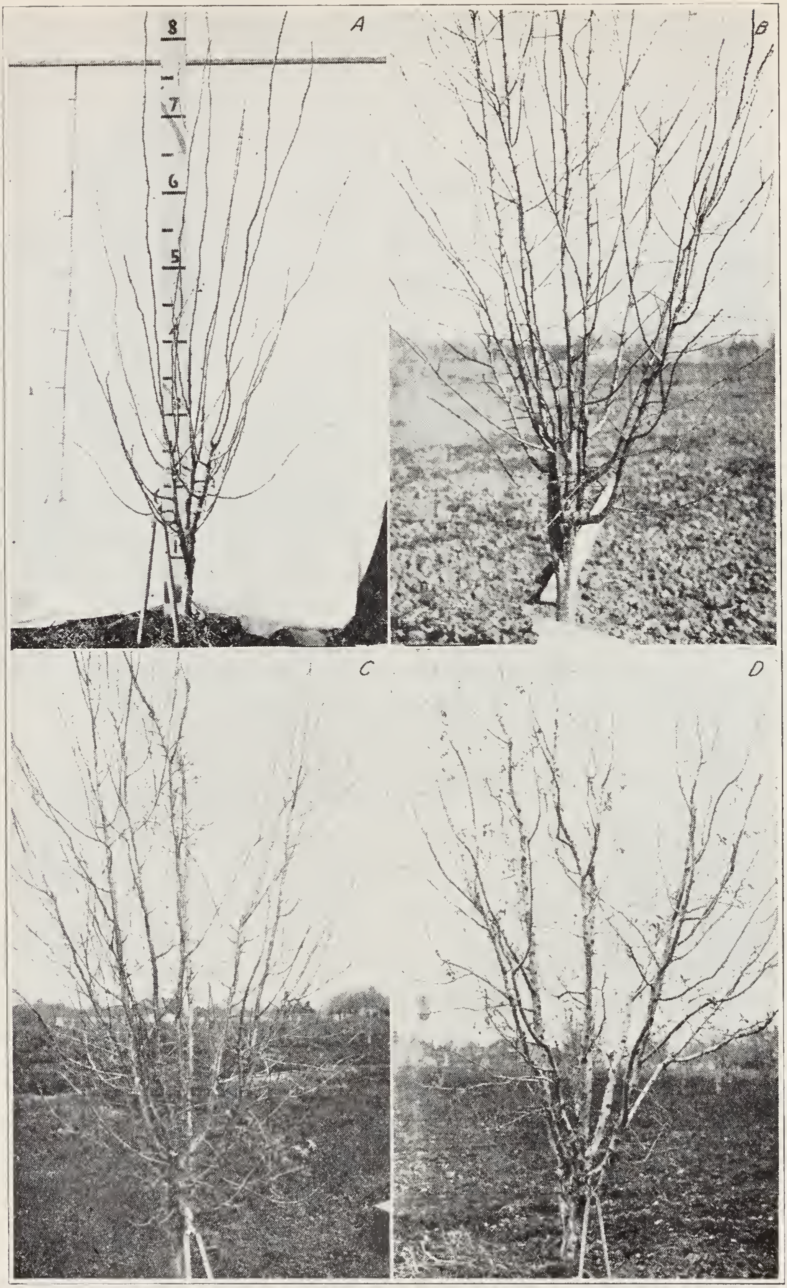

Fig. 1.—A typical French prune tree at Davis: *A*, at 2 years of age; *B*, at 3 years; *C*, at 4 years; and *D*, at 7 years.

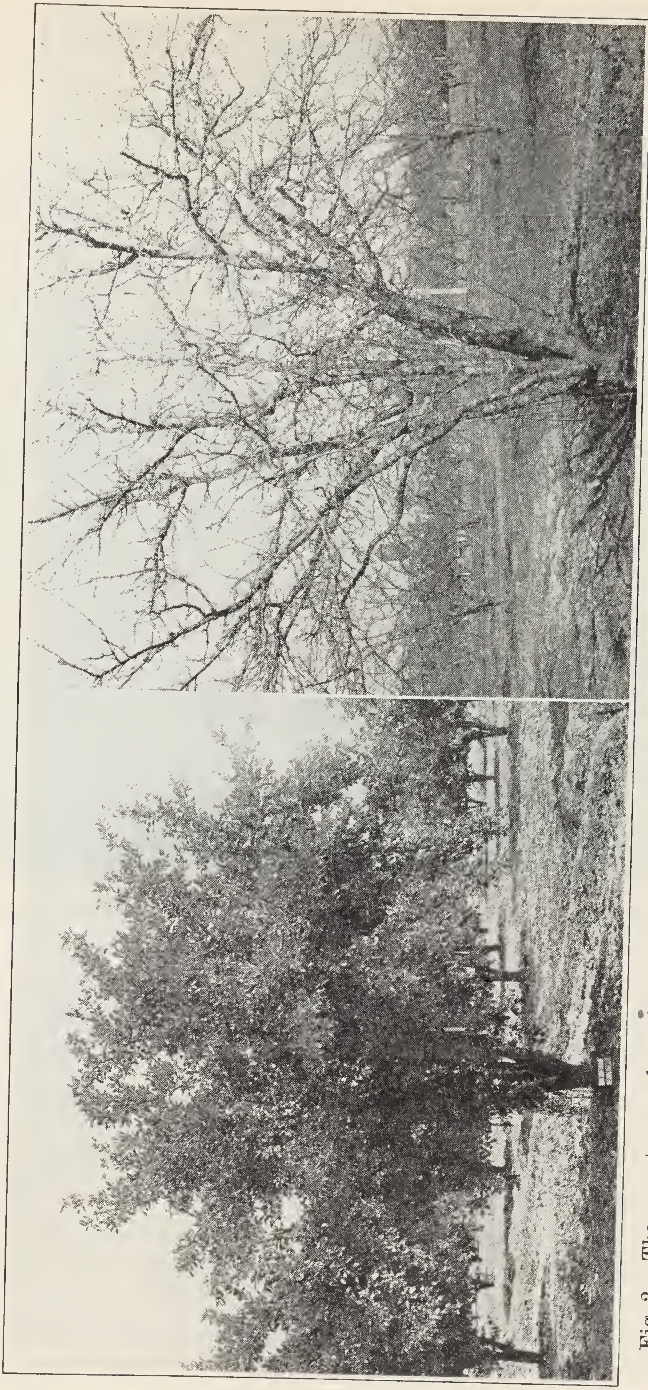

Fig. 2.—The same tree as shown in figure 1: left, during the summer of the sixteenth year; and right, in the following winter.

All trees have been sprayed each summer, chiefly to control aphids and red spiders, but no winter sprayings have yet been necessary. Though satisfactory control was usually secured, the crop was materially affected by red spiders one year, as will be described later.

Fig. 3.—Method of irrigation used in the experimental orchard. Photographed October 5, 1923.

The usual practice was to disk the native weeds in March and not to cultivate again before the first irrigation, unless numerous weeds appeared. After the March cultivation, the soil in the unirrigated plots was left untouched, except to smooth it just before harvest. Whenever irrigation was necessary on certain plots, ridges were thrown up, enclosing each tree in a square basin (fig. 3). After irrigation, the ridges were cultivated lightly to fill the cracks through which leaks might occur next time, but the remaining soil was undisturbed. Thus, the basins were used two or three times without being torn down and remade. Shortly before harvest the entire orchard was cultivated and smoothed to facilitate picking. Plots that subsequently received no water were not cultivated further. On those irrigated after harvest, the ridges were

plowed down to facilitate winter pruning and brush-burning. Neither covercrops nor fertilizers were used.

The soil is classified as a Yolo loam. Below 3 feet, layers of sand or fine gravel are sometimes encountered. No outstanding differences in tree behavior were caused by the varying soil texture. Before the orchard was planted, the area had produced small grains and alfalfa; but no fertilizers had been added for at least seven years before the trees were set out.

OUTLINE OF THE EXPERIMENT

Obviously, with comparatively few trees available, the different treatments must be few, and the number of replications limited. Each experimental row of trees was completely surrounded by guard trees receiving the same irrigation treatment. In other words, somewhat less than one-third of all trees were available for close study. After careful consideration, the plots were laid out as shown in figure 4.

The plots for the different treatments were selected according to the growth measurements of the trees for the first 6 years after planting. During this time, all trees were kept as healthy and vigorous as possible. At first the length of the new shoots was measured with a centimeter rule, and the circumference of the trunk about 6 inches above the bud union was measured with a steel tape. After the trees were several years old, however, the large number of new shoots made the length measurement impracticable, so that after 1920 the trunk measurement was used as the sole index to growth.[5] The coefficients of correlations between length growth of new shoots and cross-section area of the trunks, as expressed statistically, were 0.74 ± 0.026 in 1919, and 0.71 ± 0.025 in 1920.

In grouping the plots for the various treatments, plots of high variability in size were placed with those of low variability. The coefficients of variability based on the cross-section area of the tree trunks, after 6 years of uniform care and before differential treatments began, are shown in table 1. The treatments are designated by letters as explained later. A plan of the orchard is shown in figure 4.

The irrigation treatments consisted in wetting the soil by the basin method, to eliminate the dry portions which, in furrow irrigation, usually hamper the interpretation of soil-moisture data (fig. 3). The time of applying water was determined by studying the soil-moisture samples taken regularly with a soil tube in each plot. The amount of water to be applied was calculated from the volume weight, the mois-

[5] Trunk circumferences of old trees may not be such reliable measurements of the fruit-producing portion of a tree as with young trees. Because of the difficulties involved in other methods, however, they are ordinarily used.

ture equivalent, and the water in the soil, and was measured over a weir. Soil samples were taken during the growing season in 3-foot increments to a depth of 6 feet at frequent intervals, at five places in each plot, and in certain years to a depth of 12 feet about once a month.

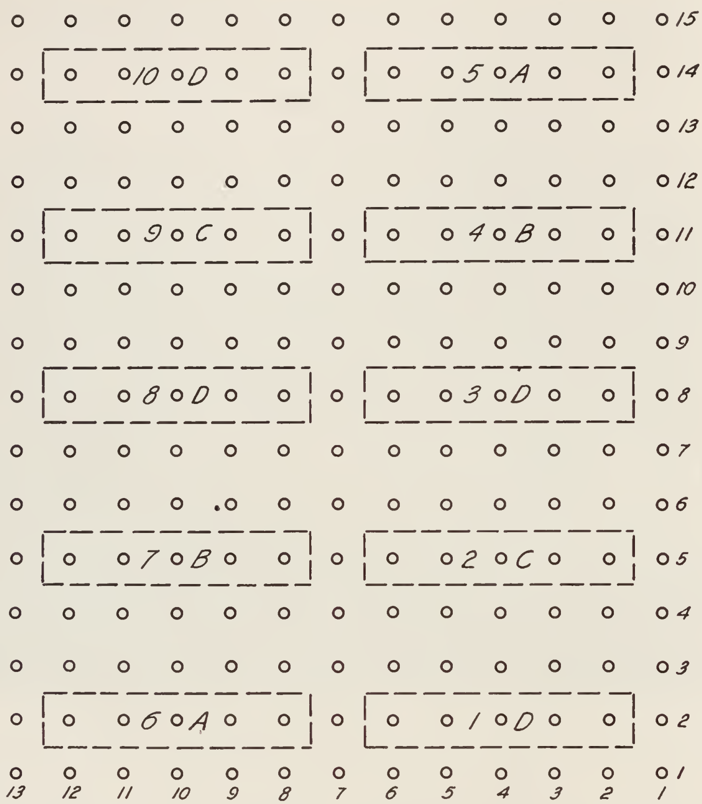

Fig. 4.—French-prune orchard at Davis, showing location of plots. The experimental trees are inclosed in the broken lines.

The plan of irrigation for each treatment is given below:

Treatment A.—The plots were kept supplied with readily available water.[6] This will be sometimes referred to as the "continuously moist treatment."

Treatment B.—The plots were irrigated before, but not after July 1.

Treatment C.—The trees were not irrigated until after July 1.

Treatment D.—No water was added to the soil during the growing season.

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[6] For definition of this term, see page 10.

The general plan was to have one treatment with continuously moist soil; one with moist soil early in the season, but with dry soil later; one with dry soil for a short time about midsummer, but with moist soil later; and one not irrigated during the growing season. Water was applied to meet these requirements as closely as possible. Because of the small size of the trees, the plan was not completely carried out during the early years; but, in 1926 and thereafter, the readily available moisture was exhausted at about the desired time.

This report gives the results of the experiments over a 10-year period, and may be considered a progress report. The experiments are being continued.

TABLE 1

COEFFICIENTS OF VARIABILITY IN SIZES OF PRUNE TREES AT DAVIS, CALIFORNIA, FROM CROSS-SECTION AREAS OF TRUNKS, IN DECEMBER, 1922

Treatment	Plot	Coefficient of variability	Treatment	Plot	Coefficient of variability
		per cent			*per cent*
D	1	8.6±1.8	A	6	7.4±1.6
C	2	12.7±2.7	B	7	6.4±1.4
D	3	10.2±2.2	D	8	7.0±1.5
B	4	16.0±3.4	C	9	3.2±0.7
A	5	11.1±2.4	D	10	7.3±1.6

PROCEDURE AND EXPERIMENTAL RESULTS

The data given in this bulletin were obtained from the following sources: soil-moisture characteristics; measured quantities of water applied to the various plots; soil-moisture determinations from samples obtained with soil tubes; annual measurements of tree growth and yields; growth measurements of the fruit; sugar and acid contents of the fresh fruit; drying ratios; specific gravity determinations; and segregations of fruit sizes after drying. The time of blossom-opening and of fruit-ripening, any injury by insect infestation, and the general condition of the trees were observed.

Moisture Properties of the Soil.—As shown by previous work with prunes,[4] certain soil-moisture conditions are important. Since the terms describing them will be used frequently, they must be briefly defined. The *moisture equivalent* is a laboratory determination of the water-holding capacity of soil under certain conditions. In fine-textured soils it is a fair measure of the field capacity[6]—that is, the amount of water retained after the excess has drained away and after the rate of downward movement has materially decreased. This moisture condition prevails in pervious soils 2 or 3 days after a rain or an irrigation. The *permanent wilting percentage* is that soil-moisture content at which

plants wilt and do not recover unless water is added to the soil. The term "readily available moisture" is applied to the range of moisture between the field capacity and about the permanent wilting percentage, since previous investigations[1] by the writers have shown no differences in the rate of soil-moisture extraction within this range. Trees may obtain some water from a soil below the permanent wilting percentage, but not enough to prevent wilting. Water-holding characteristics of soils are described more fully in Extension Circular 50.[7]

Previous work[4] shows that soil moisture could fluctuate between wide limits without affecting orchard trees. The experiment was planned, therefore, to allow the trees in certain treatments to reduce the soil moisture to the lower limit instead of applying stated quantities of water at definite intervals. At the start, in 1923, this lower limit was generally believed to be the "wilting coefficient," obtained by dividing the moisture equivalent by the factor 1.84. This wilting coefficient was used for several years to measure the limit below which the trees would not extract moisture readily. As was shown later,[5] however, it does not always agree with the soil-moisture content at which plants wilt; and the permanent wilting percentage does not bear a constant relation to the moisture equivalent, but must be determined for each soil by observing the plants in the field, by growing indicator plants in containers, or by studying the soil-moisture extraction curves.

The permanent wilting percentages used were obtained from the points on the soil-moisture extraction curves that indicated a markedly reduced rate of extraction, and from growing and wilting sunflower plants on composite samples of the various depths obtained from each plot. Though the "wilting coefficients" used early in the experiment differed from the permanent wilting percentages, these differences were soon discovered and did not affect the experimental results.

Table 2 gives certain soil-moisture characteristics. The moisture equivalents varied considerably at the different depths sampled. In general, the 3 to 6-foot depth has an average moisture equivalent considerably lower than that in the other depths.

Although the soil in the experimental area proved to be fairly uniform, individual moisture equivalents and permanent wilting percentages varied widely from the average. Similar variations are ordinarily encountered and must be considered in interpreting experimental data.

Using a small number of determinations is somewhat hazardous when the results will be applied to the whole area. In the present experiment the moisture equivalents were obtained from hundreds of samples; and the moisture curves, shown later, are also averages of many determinations for soil-moisture content. Obviously, the moisture equivalents and

permanent wilting percentages from one corner of a field would probably not agree exactly with those from the opposite corner, even in a soil apparently as uniform as the one used. Individual determinations of the moisture equivalent varied from the averages given, possibly because of the undulating layers of different-textured soil beneath the surface. The extreme variation of the moisture equivalent at a given depth ranged from about 3.5 per cent below to about 4.0 per cent above the average.

TABLE 2

Moisture Equivalents and Permanent Wilting Percentages of Soil in Experimental Plots

Depth of soil, feet	Moisture equivalent	Permanent wilting percentage	Depth of soil, feet	Moisture equivalent	Permanent wilting percentage
Treatment A			Treatment C		
0 to 3	20.1	9.9	0 to 3	20.2	9.8
3 to 6	16.4	8.4	3 to 6	14.5	8.0
6 to 9	20.9	9.0	6 to 9	21.2	9.4
9 to 12	23.9	8.7	9 to 12	24.0	10.7
Treatment B			Treatment D		
0 to 3	21.0	9.9	0 to 3	21.4	9.8
3 to 6	14.2	8.4	3 to 6	15.1	7.8
6 to 9	18.3	8.9	6 to 9	17.8	10.6
9 to 12	20.2	9.5	9 to 12	20.8	10.3

Irrigation of the Plots.—The amounts of water applied to the different plots are given in table 3. Because of the low rainfall in the winters of 1928–29 and 1930–31, as shown in table 4, all plots were sufficiently irrigated in late winter to insure having the soil wet to a depth of 6 feet at the beginning of the growing season. The amount of water applied at this time is not included in the totals in table 3.

The trees in treatment A received the most water except in 1932, when one plot in C received more than did one in A. In general, the plots, in A received two or three irrigations during the growing season until 1929, and four irrigations in 1929 and thereafter. One irrigation each year was applied after harvesting. The more frequent irrigations toward the end of the 10-year period were necessitated by the increased tree size. The soil moisture in these plots was maintained above the permanent wilting percentage throughout the year.

The trees in treatment B were irrigated once annually from 1923 to 1928, inclusive, and in 1932; and twice each year in 1929, 1930, and 1931. The irrigations were applied before July 1 each year. The average application of water to treatment B was less than that given to C.

TABLE 3

WATER APPLIED TO ORCHARD IN ACRE-INCHES PER ACRE

Date	Treatment A		Treatment B		Treatment C	
	Plot 5	Plot 6	Plot 4	Plot 7	Plot 2	Plot 9
1923						
May 19-22	3.6	5.3	5.1	5.9	0.0	0.0
July 20-24	6.0	4.8	0.0	0.0	6.4	6.4
Oct. 5- 8	4.1	4.4	0.0	0.0	4.9	4.5
Total	13.7	14.5	5.1	5.9	11.3	10.9
1924						
June 10-13	4.8	4.9	6.6	5.3	0.0	0.0
Sept. 12-13	5.5	6.3	0.0	0.0	6.6	7.0
Total	10.3	11.2	6.6	5.3	6.6	7.0
1925						
June 25-26	3.8	3.5	3.7	2.8	0.0	0.0
July 28-30	0.0	0.0	0.0	0.0	7.5	3.9
Aug. 14	5.0	4.5	0.0	0.0	0.0	0.0
Oct. 5- 6	3.0	3.0	0.0	0.0	3.0	3.0
Total	11.8	11.0	3.7	2.8	10.5	6.9
1926						
June 18-20	5.5	5.6	5.6	5.1	0.0	0.0
July 24	0.0	0.0	0.0	0.0	5.0	5.0
Aug. 27-28	6.8	6.6	0.0	0.0	4.9	3.7
Total	12.3	12.2	5.6	5.1	9.9	8.7
1927						
June 9-10	5.0	5.2	3.6	3.7	0.0	0.0
July 15	4.7	4.3	0.0	0.0	7.0	7.2
Oct. 4	4.0	4.0	0.0	0.0	4.0	4.0
Total	13.7	13.5	3.6	3.7	11.0	11.2
1928						
June 22-25	10.1	10.1	10.1	10.1	0.0	0.0
July 18-20	0.0	0.0	0.0	0.0	9.5	9.5
July 31	4.0	4.0	0.0	0.0	0.0	0.0
Sept. 27-28	6.0	6.0	0.0	0.0	6.0	6.0
Total	20.1	20.1	10.1	10.1	15.5	15.5
1929						
May 17-18	5.8	7.1	5.8	5.8	0.0	0.0
June 24-25	4.8	4.8	4.8	4.8	0.0	0.0
July 26-29	5.1	5.1	0.0	0.0	8.6	8.6
Sept. 30-Oct. 1	5.3	5.3	0.0	0.0	5.3	5.3
Total	21.0	22.3	10.6	10.6	13.9	13.9
1930						
May 23-24	7.2	7.2	7.2	7.2	0.0	0.0
June 26-27	5.6	5.6	5.6	5.6	0.0	0.0
July 17	0.0	0.0	0.0	0.0	7.0	7.0
July 31	6.0	6.0	0.0	0.0	0.0	0.0
Sept. 22-24	6.6	6.6	0.0	0.0	6.6	6.6
Total	25.4	25.4	12.8	12.8	13.6	13.6
1931						
June 2-3	8.0	8.0	8.0	8.0	0.0	0.0
June 25	5.6	5.6	5.6	5.6	0.0	0.0
July 16	0.0	0.0	0.0	0.0	11.9	11.9
July 27	8.0	8.0	0.0	0.0	0.0	0.0
Sept. 2-4	8.9	8.9	0.0	0.0	8.9	8.9
Total	30.5	30.5	13.6	13.6	20.8	20.8
1932						
June 17-18	7.3	7.7	7.3	7.7	0.0	0.0
July 11-12	4.8	7.5	0.0	0.0	8.8	12.5
Aug. 10-11	8.0	8.1	0.0	0.0	7.5	8.1
Sept. 23-24	5.9	5.9	0.0	0.0	6.3	6.5
Total	26.0	29.2	7.3	7.7	22.6	27.1

The trees in C were not irrigated before July 1. In 1924 it received no irrigation; in 1932, two irrigations; and in the other years, one irrigation before harvesting. In addition, these trees were irrigated each year after harvesting. In general, treatment C received less water than A, but more than B. Throughout the experiment, no water was applied to the trees in D in the growing season; but this treatment received a late winter irrigation in 1929 and in 1931, because of deficient rainfall.

TABLE 4

Rainfall at Davis, in Inches

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	Total
1922-23	0.00	0.00	0.00	1.56	3.29	7.37	2.62	0.70	0.00	2.22	0.10	0.00	17.86
1923-24	0.00	0.00	0.35	0.40	0.53	0.88	2.46	2.76	1.18	0.38	0.05	0.00	8.99
1924-25	0.00	0.00	0.00	2.05	1.42	3.55	1.05	4.28	3.10	2.15	1.63	0.02	19.25
1925-26	0.00	0.03	0.10	0.01	1.71	1.29	3.70	5.50	0.01	5.74	0.26	0.00	18.35
1926-27	0.00	0.01	0.00	2.01	5.18	0.73	2.18	4.66	1.07	2.48	0.31	0.47	19.10
1927-28	0.00	0.00	0.00	1.71	2.91	2.32	1.73	1.62	3.45	0.75	0.27	0.00	14.76
1928-29	0.00	0.00	0.00	0.13	3.19	2.74	0.63	1.56	1.34	0.34	0.01	0.94	10.88
1929-30	0.00	0.00	0.00	0.09	0.00	3.77	3.80	1.66	3.48	0.92	0.18	0.00	13.90
1930-31	0.00	0.00	0.23	0.69	0.92	0.20	3.71	1.02	0.85	0.00	0.80	0.31	8.73
1931-32	0.00	0.00	0.00	0.17	1.36	7.84	1.35	1.67	2.01	0.66	0.15	0.00	15.21
Mean	0.00	0.004	0.07	0.88	2.05	3.07	2.33	2.54	1.65	1.56	0.38	0.17	14.70

Soil-Moisture Conditions.—The soil-moisture records are given in tables 5 and 6. For 1928, 1930, and 1932, they are also shown graphically in figures 5, 6, 7, and 8. They are typical of records obtained during the last half of the experiment. The downward slopes from left to right show how fast the trees used water, while the sharp upward slopes indicate when irrigation water was applied.

In treatment A, according to the soil-moisture records, the moisture content, except for a brief period in late September, 1927, was maintained above the permanent wilting percentage in the top 6 feet throughout the study. During the last half of the experiment, there was available water in the 6 to 9-foot depth, and during the last 3 years, in the 9 to 12-foot depth also. Occasional samples indicated available moisture at all times in the 6 to 12-foot depth during the early years of the experiment. In general, water was used more rapidly from the 0 to 3 than from the 3 to 6-foot depth, and more rapidly from both these than from the 6 to 9 and the 9 to 12-foot depths.

In treatment B the trees were supplied with available soil moisture until late summer. Even though these plots received no irrigation after July 1, the permanent wilting percentage was not reached in the latter part of the season in the top 6 feet of soil until 1926, when it was reached late in September. The permanent wilting percentage was reached in the

upper 6 feet on the following approximate dates: August 19, 1927; August 28, 1928; August 23, 1929; August 20, 1930; September 15, 1931; and August 9, 1932. In addition, it was almost reached in the 6 to 9-foot depth late in the season in the years 1927 to 1932, with the

TABLE 5

AVERAGE SOIL-MOISTURE PERCENTAGES; 1923 TO 1926, INCLUSIVE

Date	Treatment A		Treatment B		Treatment C		Treatment D	
	0-3 ft.	3-6 ft.	0-3 ft.	3-6 ft.	0-3 ft.	3-6 ft.	0-3 ft.	3-6 ft.
1923								
May 11	15.1	15.5	14.7	13.6	14.9	14.8	15.5	14.3
May 26	20.1	16.2	20.3	16.0	....	....	....	....
July 3	14.3	14.0	14.7	12.6	11.9	11.3	12.5	11.8
July 27	19.1	15.4	....	....	20.6	15.9	....	....
Sept. 5	15.5	15.3	11.4	11.4	17.8	15.7	10.2	10.1
Oct. 1	14.7	14.7	....	....	14.0	13.2	....	....
Oct. 8	20.9	17.7	....	....	23.3	16.5	....	....
Dec. 4	18.5	18.1	11.8	11.7	17.8	15.7	10.6	9.7
1924								
April 1	16.6	16.5	15.5	11.2	16.7	16.6	15.6	9.4
May 29	13.2	14.1	12.3	11.3	12.5	12.1	12.4	10.0
June 17	18.4	14.6	18.8	12.5	....	....	....	....
July 30	13.7	13.7	14.6	12.5	11.5	12.4	11.2	9.9
Sept. 2	12.2	12.9	12.3	11.1	10.9	11.6	9.7	9.4
Sept. 16	21.4	15.9	....	....	21.6	13.2	....	....
Nov. 21	17.7	15.0	14.3	10.5	16.7	12.8	13.1	9.5
1925								
April 7	22.3	18.8	22.8	18.8	22.8	17.9	22.8	15.5
May 28	15.4	15.5	15.8	14.7	15.5	15.0	15.7	14.7
June 16	14.3	15.6	14.8	14.2	....	....	....	....
July 16	15.3	14.3	15.7	13.4	13.4	10.9	11.4	11.8
Aug. 3	14.3	13.1	....	....	19.2	15.4	....	....
Aug. 19	20.4	16.8	....	....	....	....	....	....
Sept. 9	17.6	16.4	13.6	12.5	15.6	13.5	11.4	11.4
Oct. 9	18.7	14.8	....	....	19.4	12.3	....	....
Oct. 30	17.5	14.2	12.4	10.8	18.0	12.4	10.5	10.1
1926								
Mar. 16	18.5	18.1	18.6	17.2	17.8	17.6	18.4	17.5
May 4	17.9	17.2	17.9	16.7	17.7	16.2	18.1	15.7
June 14	13.2	12.7	12.9	12.6	12.7	12.3	13.2	12.5
June 23	20.4	16.8	22.6	17.4	....	....	....	....
July 23	13.5	12.5	13.5	12.0	10.6	9.3	10.0	9.6
Aug. 19	12.3	11.0	11.5	10.2	16.8	13.8	10.0	9.8
Sept. 1	20.8	16.8	....	....	20.6	13.2	....	....
Sept. 29	15.3	13.4	10.3	9.3	14.7	11.6	9.5	9.1

exception of 1930. The 9 to 12-foot depth, however, contained some readily available water throughout the last 3 years of the experiment and probably, therefore, during the other years as well. From 1927 to 1932, inclusive, the trees were permanently wilted from one to three weeks before harvesting.

TABLE 6

Average Soil-Moisture Percentages; 1927 to 1932, Inclusive

Date	Treatment A				Treatment B				Treatment C				Treatment D			
	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.
1927																
April 19	19.2	17.2	21.9	....	20.0	16.8	15.6	....	19.2	16.0	21.0	....	20.3	15.6	14.6	....
May 10	16.2	15.5	20.8	....	17.2	15.7	16.1	....	16.7	15.1	20.7	....	18.3	15.3	14.1	....
June 2	12.9	13.8	19.5	....	14.4	14.4	15.3	....	13.3	12.8	19.1	....	14.2	13.3	14.4	....
June 13	22.0	18.8	24.2	....	20.6	16.6	20.4	....	....	....	....	....	....	....	....	....
June 21	17.9	16.1	22.8	....	16.7	14.6	18.4	....	12.0	10.6	18.7	....	12.7	11.1	13.9	....
July 7	14.0	13.9	20.3	....	13.8	12.3	16.6	....	11.2	10.0	16.6	....	11.0	10.4	13.2	....
July 20	19.5	16.4	22.7	....	11.4	10.7	15.8	....	20.7	17.2	22.5	....	10.5	9.3	13.5	....
Aug. 19	12.4	11.8	16.6	....	10.0	9.3	12.7	....	12.8	11.6	17.6	....	9.8	8.8	12.4	....
Sept. 30	9.6	9.0	11.2	....	9.1	8.6	10.4	....	10.1	9.2	14.1	....	8.8	8.3	11.3	....
Oct. 12	16.7	12.0	14.4	....	....	....	....	....	17.6	13.3	16.5	....	....	....	....	....
1928																
April 13	18.8	15.8	14.6	....	20.1	11.6	11.2	....	19.1	15.7	16.2	....	19.2	12.0	11.6	....
May 15	14.9	14.8	14.8	....	14.9	10.7	11.5	....	15.2	14.0	15.9	....	15.1	10.8	11.4	....
June 20	11.2	10.1	13.5	....	10.9	9.4	10.8	....	11.6	10.7	15.1	....	11.3	9.4	11.2	....
June 28	21.7	16.2	21.0	....	22.7	16.7	17.6	....	....	....	....	....	....	....	....	....
July 17	15.1	14.8	19.0	....	15.1	13.0	16.8	....	10.0	9.1	12.9	....	10.2	8.3	10.5	....
July 26	13.3	12.3	18.2	....	....	....	....	....	19.3	15.4	22.5	....	....	....	....	....
Aug. 4	20.7	19.3	20.5	....	....	....	....	....	....	....	....	....	....	....	....	....
Aug. 28	14.3	12.3	18.6	....	9.8	8.9	12.7	....	13.2	11.1	17.3	....	9.1	8.2	11.0	....
Sept. 24	10.6	10.1	13.6	....	9.0	8.2	10.2	....	9.9	9.8	12.7	....	8.4	7.9	9.7	....
Oct. 10	18.1	15.8	21.2	....	....	....	....	....	17.8	15.2	21.4	....	....	....	....	....
1929																
Mar. 28	17.4	14.3	17.2	....	17.0	10.2	11.1	....	17.2	14.6	16.0	....	16.4	9.7	12.8	....
April 19	....	....	....	....	....	....	....	....	....	....	....	....	21.4	16.6	15.0	....
May 15	13.6	14.0	17.2	....	12.9	9.4	10.6	....	13.3	13.3	15.8	....	17.1	13.8	14.5	....
May 24	22.5	17.4	21.9	....	20.4	16.2	13.4	....	....	....	....	....	....	....	....	....
June 3	17.0	15.8	21.2	....	16.6	13.9	13.3	....	11.8	10.6	15.2	....	14.1	12.5	13.3	....
June 19	15.5	15.6	19.6	....	14.8	10.8	13.4	....	11.6	9.8	14.6	....	13.4	11.0	13.2	....
June 29	21.2	19.3	23.7	....	20.6	16.2	20.8	....	....	....	....	....	....	....	....	....
July 22	13.2	12.7	20.4	....	12.6	12.2	17.5	....	9.3	8.4	11.7	....	10.2	8.6	11.3	....

TABLE 6—*(Continued)*

Date	Treatment A				Treatment B				Treatment C				Treatment D			
	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.
1929																
Aug. 5	19.9	14.0	18.8	....	....	....	....	....	20.4	16.7	22.2	....	....	....	....	....
Aug. 23	14.0	11.0	15.4	....	9.9	9.0	12.6	....	14.0	13.2	19.5	....	9.2	8.3	10.8	....
Sept. 12	11.2	9.8	13.8	....	9.4	8.3	11.2	....	12.0	10.6	16.2	....	9.0	8.3	10.5	....
Sept. 26	11.0	9.8	12.6	....	9.2	8.8	11.2	....	10.5	9.3	14.0	....	9.0	8.2	10.6	....
Oct. 12	20.6	15.0	14.8	....	9.0	8.2	10.8	....	20.2	14.6	19.0	....	8.7	7.9	10.3	....
Oct. 25	15.8	12.8	14.2	....	8.5	8.3	10.5	....	16.6	13.1	17.2	....	8.7	7.9	10.6	....
Nov. 8	14.2	12.0	13.9	....	8.9	8.3	10.5	....	15.2	12.4	16.5	....	9.0	7.8	10.6	....
Nov. 29	13.4	11.2	13.8	....	8.8	8.0	10.7	....	13.4	11.6	13.2	....	8.6	7.8	10.1	....
1930																
April 8	17.6	16.0	17.2	16.2	17.6	14.6	11.3	14.8	17.7	14.7	18.0	17.0	18.0	14.8	11.4	14.9
April 22	16.6	15.6	17.7	16.3	16.6	14.4	12.1	15.2	16.6	13.8	17.0	17.0	17.0	14.4	11.6	15.4
May 6	15.2	14.0	16.8	16.0	15.0	14.0	12.0	14.7	15.0	13.2	17.3	17.0	15.5	13.2	12.0	14.0
May 20	13.2	12.6	16.6	16.0	13.6	12.4	11.6	14.8	13.4	12.0	16.0	17.0	13.9	12.4	11.3	14.6
May 27	19.6	15.4	21.1	21.6	21.2	15.8	19.0	16.9	....	....	....	....	....	....	....	....
June 3	17.9	16.2	20.7	19.0	18.1	15.6	21.2	19.4	11.4	10.8	16.0	16.6	12.0	10.7	11.6	14.5
June 18	13.6	13.0	18.2	17.8	13.2	12.8	18.6	18.1	10.0	9.0	15.0	16.0	10.3	9.9	11.4	13.0
June 26	13.0	12.7	18.8	17.2	13.0	12.0	18.8	18.2	....	....	....	....	....	....	....	....
July 1	20.6	18.0	22.2	20.4	18.0	14.1	21.4	18.5	9.5	8.3	13.8	15.4	9.6	8.8	11.2	13.7
July 15	14.4	13.3	18.6	19.8	13.8	13.0	18.6	20.6	9.2	8.1	13.4	15.8	9.4	8.8	10.8	14.5
July 21	....	....	....	....	....	....	....	....	18.8	14.0	18.5	18.2	....	....	....	....
July 29	11.5	11.2	16.3	19.0	11.2	10.2	15.6	19.4	14.0	11.3	18.9	17.4	9.0	8.1	10.1	13.3
Aug. 4	19.8	15.7	18.8	20.4	....	....	....	....	....	....	....	....	....	....	....	....
Aug. 20	14.8	12.8	16.6	18.8	9.7	9.2	13.2	16.2	11.1	9.6	16.0	16.6	8.5	8.2	10.4	13.0
Sept. 12	12.4	11.6	15.6	17.4	9.0	8.4	12.7	16.4	9.2	8.3	14.8	15.2	8.1	8.0	10.4	12.8
Sept. 20	11.6	9.6	14.0	16.7	....	....	....	....	9.5	8.1	14.0	14.6	....	....	....	....
Sept. 30	19.0	12.7	14.4	18.2	9.4	8.9	12.6	16.6	17.6	9.8	13.6	16.6	8.5	8.0	10.8	13.0
Nov. 4	14.0	13.1	14.9	17.4	9.4	8.7	11.8	16.6	13.8	12.1	18.0	15.8	8.7	8.0	9.7	11.7

TABLE 6—(*Concluded*)

Date	Treatment A				Treatment B				Treatment C				Treatment D			
	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.	0-3 ft.	3-6 ft.	6-9 ft.	9-12 ft.
1931																
April 14	17.0	14.4	14.2	16.4	16.3	11.2	12.6	14.0	17.6	14.3	18.1	15.6	16.4	12.2	14.7	12.6
May 28	12.1	11.2	13.6	16.3	12.0	9.7	12.5	13.8	12.4	11.0	14.2	15.6	13.0	10.0	11.5	12.3
June 10	19.6	15.9	19.2	17.4	20.0	15.0	20.0	15.6	11.4	9.6	14.0	15.0	11.7	8.9	11.3	12.4
June 23	16.4	14.8	19.0	17.8	16.5	12.8	17.6	17.8	10.4	9.0	13.8	15.2	10.8	8.5	11.5	12.6
June 30	20.2	15.4	17.1	17.0	19.9	13.0	12.4	14.7	....	....	....	....	10.0	8.4	11.0	12.3
July 13	....	....	....	....	....	....	....	....	9.6	8.9	12.2	13.8	....	....	....	....
July 24	12.6	12.8	18.8	18.0	....	....	....	....	17.8	12.6	15.8	14.8	....	....	....	....
Aug. 4	19.8	18.2	19.6	17.8	12.9	10.2	14.5	16.8	15.4	12.2	16.7	15.6	....	....	....	....
Aug. 17	....	....	....	....	....	....	....	....	....	....	....	....	9.2	8.0	10.7	12.0
Sept. 2	12.6	13.6	16.5	18.8	....	....	....	....	11.8	10.1	14.6	16.0	....	....	....	....
Sept. 11	19.9	16.6	21.1	20.2	10.7	9.6	11.7	17.1	18.9	14.3	18.6	18.4	8.9	7.8	9.8	12.4
Oct. 24	13.5	13.5	17.7	20.3	9.4	8.9	10.9	13.2	13.2	12.3	14.4	14.7	8.4	7.6	9.9	12.3
Nov. 19	15.5	13.9	16.9	21.0	12.1	9.4	10.7	13.0	15.0	12.2	16.3	15.9	10.9	8.0	10.0	12.0
1932																
Mar. 9	17.2	16.0	19.6	24.0	18.0	16.6	16.6	14.4	17.8	16.8	22.6	19.2	17.4	16.1	12.6	13.0
Mar. 31	18.7	16.8	22.3	26.1	19.5	16.9	19.2	16.2	19.4	16.8	23.9	23.8	19.0	16.3	15.2	13.7
May 16	14.2	14.3	21.2	24.6	13.7	14.0	17.6	16.6	14.3	13.8	21.5	22.9	15.0	14.1	15.1	13.4
June 16	11.8	11.5	17.6	23.9	11.6	10.8	15.2	15.4	10.8	9.2	17.2	19.6	11.8	10.9	13.1	13.2
June 24	18.9	15.3	19.8	23.0	18.7	11.9	14.7	14.8	....	....	....	....	....	....	....	....
July 7	15.1	13.4	17.8	21.8	14.4	12.0	15.8	16.8	10.3	9.2	15.4	18.3	10.6	9.6	13.1	14.0
July 20	18.5	13.2	18.2	24.2	12.8	11.4	15.0	17.7	20.6	15.9	18.1	19.6	10.4	9.2	11.7	12.8
Aug. 9	12.7	11.3	16.6	23.2	10.4	8.8	11.6	14.2	15.2	14.3	20.3	20.1	9.3	8.5	11.4	13.6
Aug. 17	20.6	16.3	17.8	23.5	....	....	....	....	21.1	16.4	23.2	22.4	....	....	....	....
Sept. 7	14.8	14.0	17.2	22.6	9.4	8.8	10.7	15.2	14.0	14.0	18.5	22.5	8.6	8.2	9.5	11.9
Sept. 23	13.4	11.9	15.5	22.4	8.8	8.0	10.2	13.2	13.2	11.8	18.1	19.4	8.1	8.1	10.6	13.2
Oct. 5	19.4	16.2	17.3	21.8	....	....	....	....	19.9	14.0	18.6	20.8	....	....	....	....
Nov. 14	14.7	14.6	17.0	22.2	9.2	8.3	10.2	12.1	14.6	13.1	16.9	19.8	8.5	8.0	10.0	12.1

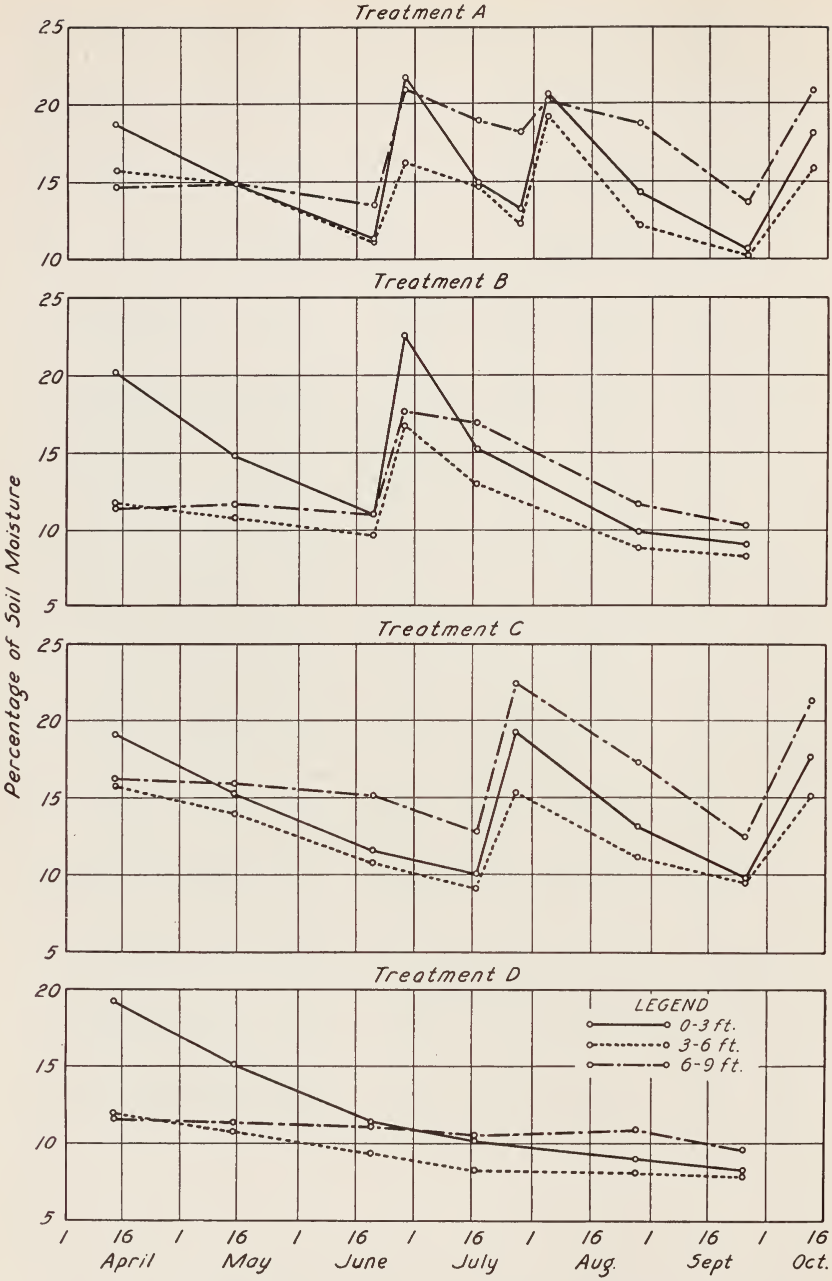

Fig. 5.—Soil-moisture conditions in the prune orchard in 1928.

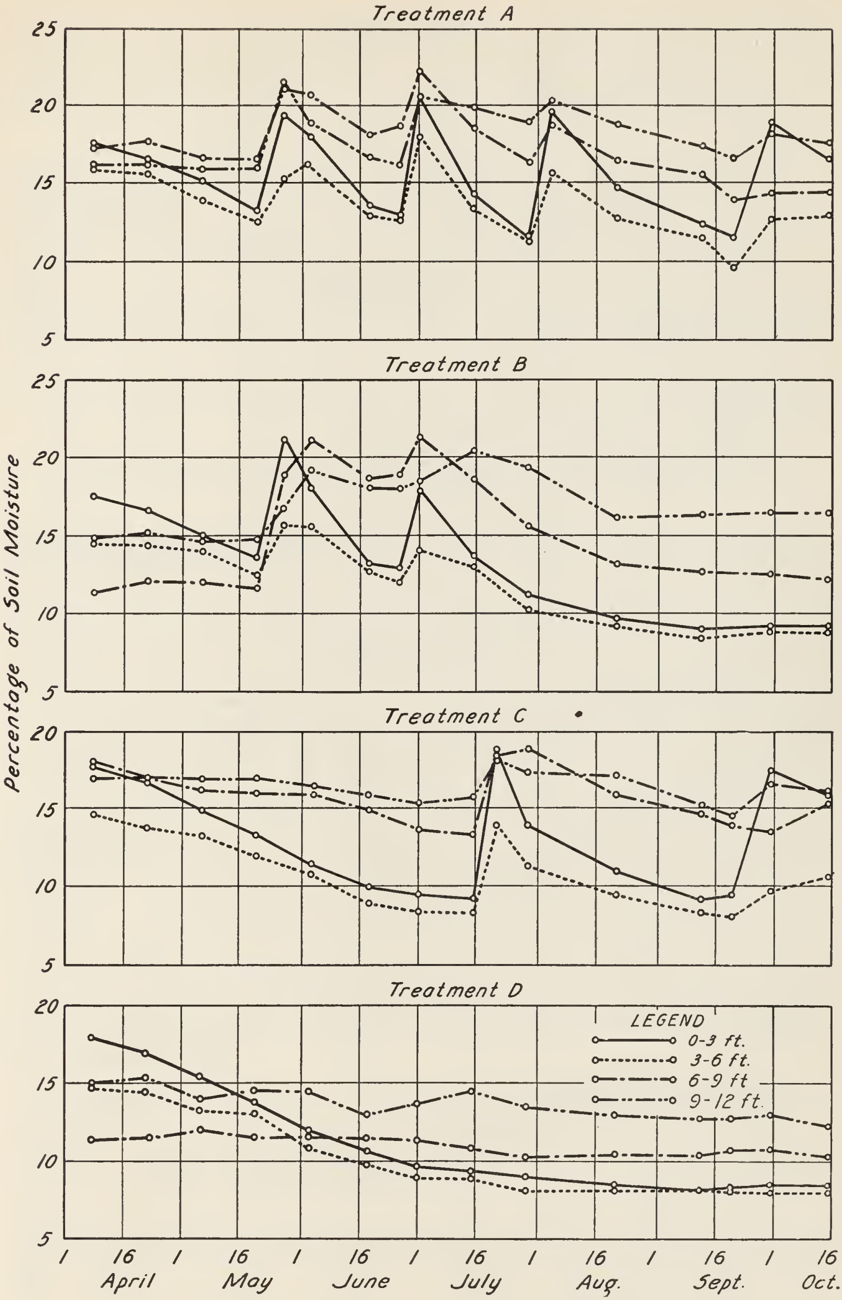

Fig. 6.—Soil-moisture conditions in the prune orchard in 1930.

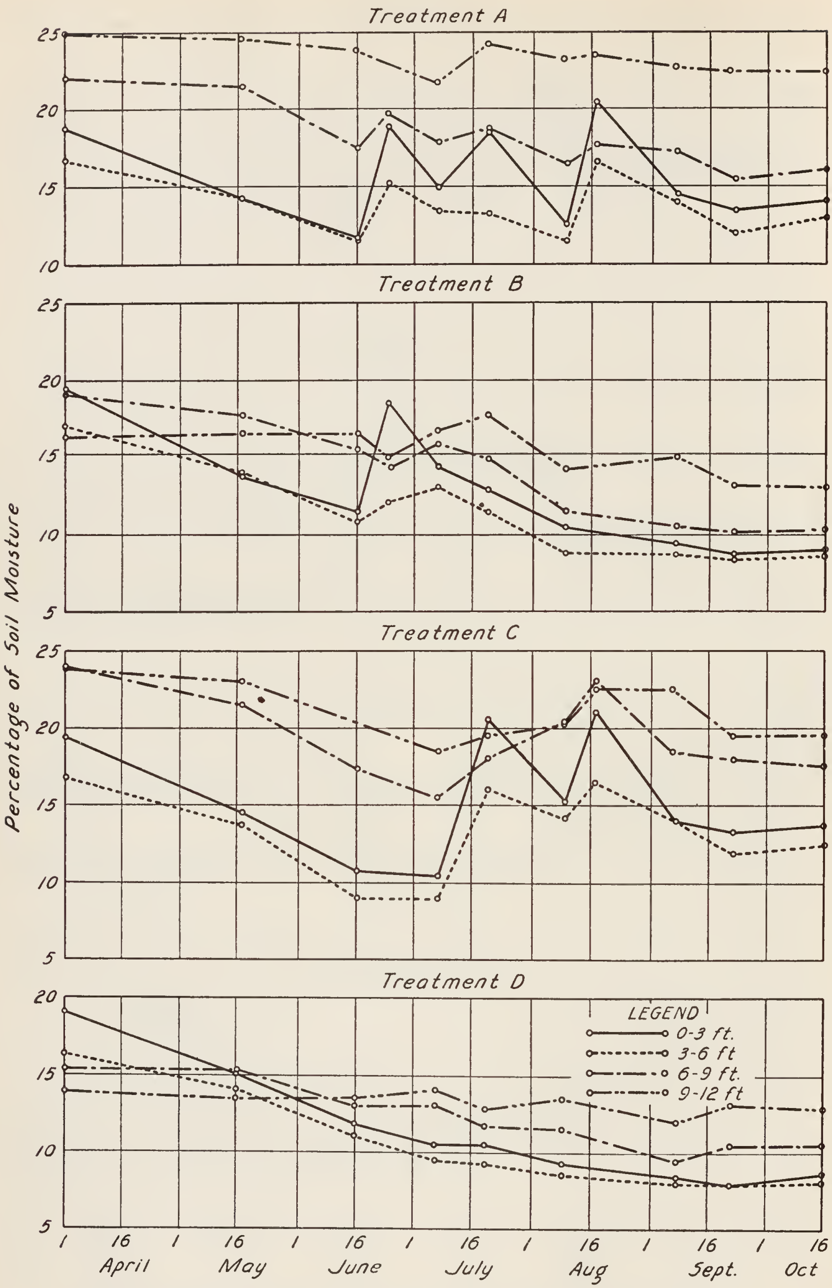

Fig. 7.—Soil-moisture conditions in the prune orchard in 1932.

In treatment C the soil was not reduced to the permanent wilting percentage in midsummer until 1928, as shown by tables 5 and 6. The average soil moisture, however, was reduced almost to the permanent wilting percentage July 23, 1926; but the area was irrigated the following day.

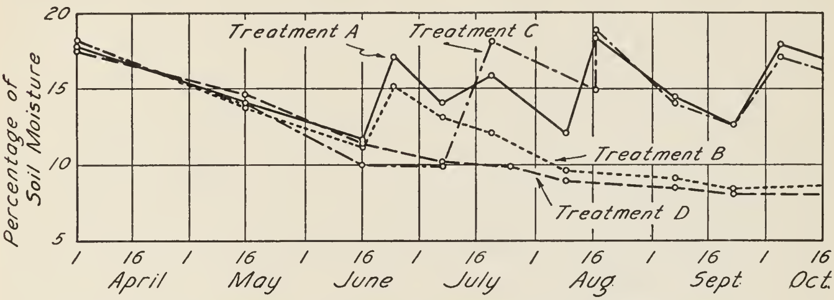

Fig. 8.—Average soil-moisture conditions in the top 6 feet in 1932.

The permanent wilting percentage in the top 6 feet of soil was reached on these approximate dates: July 15, 1928; July 22, 1929; June 18, 1930; June 23, 1931; and June 16, 1932. The trees were sometimes wilted for a few days late in the season because the irrigation was delayed to permit completion of the harvest. The permanent wilting percentage was reached about one month earlier in 1932 than in 1928, probably because of the increased tree size. The approximate period when the soil-moisture content remained at the wilting percentage, during the last 5 years of the experiment, is indicated by the irrigation and soil-moisture records in tables 3 and 6. The periods when the trees lacked readily available water up to 1930 were short; but in 1930, 1931, and 1932 they lasted about three weeks. As shown by the records for the last half of the experiment, some soil moisture was extracted from the 6 to 9 and the 9 to 12-foot depths, but was never exhausted. Since readily available moisture was found below 6 feet during the last half, it was probably present there during the early years also. Its presence at these lower depths did not prevent wilting.

In treatment D, in 1923, the average soil moisture was reduced to the permanent wilting percentage by September 5, in the upper 3 feet, but not in the 3 to 6-foot depth. In 1924, the 0 to 3-foot depth reached the permanent wilting percentage about September 2, while the 3 to 6-foot depth was close to it all season. From September 5, 1923, furthermore, until after November 21, 1924, the moisture content of the 3 to 6-foot depth was practically unchanged. In 1925, apparently little, if any, moisture was extracted after about July 15, because the trees were almost defoliated by red spiders. In 1926, the permanent wilting percent-

age was reached in the upper 3 feet about July 15, and almost reached in the second 3 feet. After the middle of the season practically no moisture was extracted, because of another red-spider infestation. The permanent wilting percentage, in the top six feet, was reached between July 20 and August 19, 1927; July 17, 1928; July 22, 1929; July 1, 1930; June 23, 1931; and July 20, 1932. The 6 to 9-foot depth contained readily available water throughout 1927. In 1928 its moisture content was close to the permanent wilting percentage but did not reach it until late in the season. In early spring of 1929, because of deficient rainfall, the plots in treatment D were irrigated. The 6 to 9-foot depth received some moisture, which was exhausted by about August 23, 1929. It reached the permanent wilting percentage about July 15, 1930. In 1931, at the beginning of the season, it contained some available soil moisture, which, however, was exhausted about June 30. In 1932 the readily available water at this depth was exhausted by about August 15. In this treatment, D, the soil-moisture conditions in the 6 to 9-foot depth were probably no more severe during the early years of the experiment than during the last half. Apparently some readily available moisture was present in the 9 to 12-foot depth during the years 1930, 1931, and 1932, and also during the earlier years.

TABLE 7

AVERAGE CROSS-SECTION AREAS OF THE TREE TRUNKS ARRANGED BY TREATMENTS

Year	Treatment A	Treatment B	Treatment C	Treatment D
	sq. cm.	*sq. cm.*	*sq. cm.*	*sq. cm.*
1919	27.7± 1.4	25.9± 1.4	23.9± 0.7	28.6±0.5
1920	49.1± 2.0	47.8± 2.3	43.4± 1.1	50.3±0.9
1921	75.6± 1.7	73.1± 2.3	67.2± 1.3	76.1±1.3
1922	115.9± 3.1	110.7± 3.9	106.5± 2.4	117.1±2.1
1923	140.6± 3.0	138.1± 4.1	131.4± 3.0	141.9±2.2
1924	178.6± 2.7	162.1± 4.6	164.8± 3.7	166.5±2.1
1925	188.7± 4.2	173.4± 5.0	170.0± 4.7	177.2±2.9
1926	249.3± 6.0	232.2± 7.1	235.7± 6.9	223.8±3.6
1927	275.7± 8.2	255.4± 7.8	256.1± 8.0	242.7±3.8
1928	304.2±11.7	277.0±11.4	284.9±15.0	258.3±4.1
1929	360.4±10.4	326.2± 9.6	328.6±10.9	294.3±5.0
1930	368.2±10.5	335.6±10.1	335.7±11.3	300.0±5.3
1931	402.9±10.7	364.3±12.1	358.1±11.6	315.8±5.3
1932	423.6±12.7	378.7±13.0	372.1±12.1	327.8±5.3

Growth of the Prune Trees.—The average cross-section areas of the tree trunks when the plots are combined by treatments are given in table 7 and figure 9. The curves show that during the first few years, when all trees had uniform treatment, the average increase in growth was essentially equal for all. Thus, from 1919 to 1922, inclusive, all trees grew at approximately the same rate; and those that, on the average, were small to start with, were the smallest at the end of this period. In 1923, when

differential irrigation treatment was started, no significant differences in size of trees were obtained. The trees in treatment A became the largest, however, in 1924, and have maintained this relative position since that time. By the end of 1924 the average cross section of their trunks was significantly larger than that in D. As previously mentioned, soil-

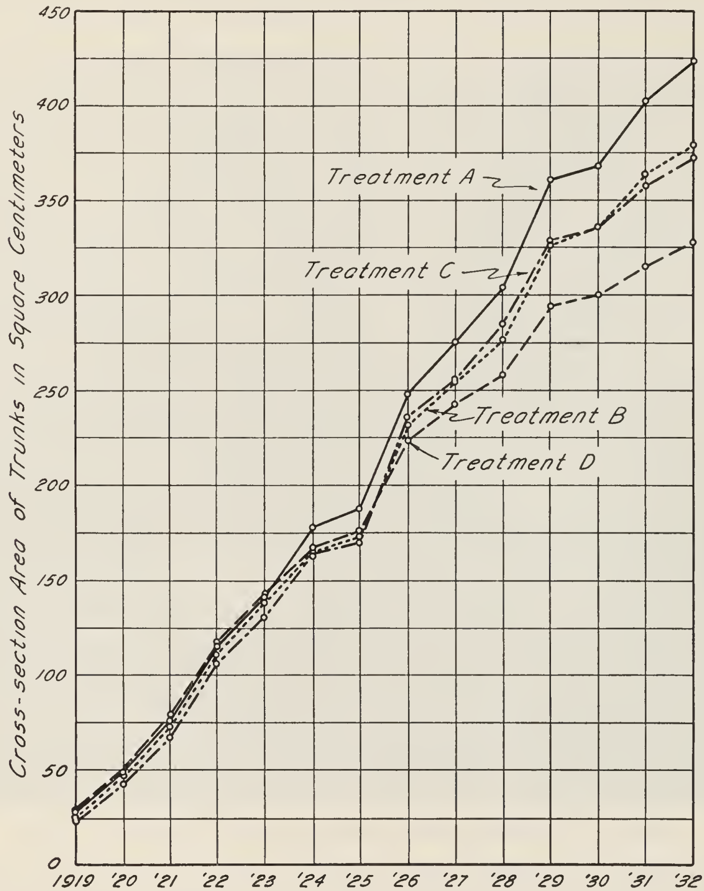

Fig. 9.—Average growth of the prune trees from 1919 to 1932, inclusive.

moisture conditions in D were severe: practically no available water was present in the 3 to 6-foot depth during the season, nor in the top 3 feet after September 2, 1924. The trees in A remained significantly larger than those in D except in 1925, when the soil moisture in the latter did not reach the permanent wilting percentage until late in the growing season.

The trees in A were always slightly larger than those in B, the difference increasing as the experiment progressed. The differences are not, however, statistically significant, though the odds calculated by the Bessel method were 10 to 1 in 1932. Odds of 30 to 1 or, where the results may be attributed to the experiment and not to chance, 29 times out of 30 are usually assumed to be significant. In this case, however, the fact that the trees in A became larger than those in B, and remained so, is

Fig. 10.—A typical prune tree in treatment A; February 1, 1933.

strong evidence that the cause was the irrigation treatment and not chance. In general, the differences between tree sizes in A and C were essentially the same as those between A and B. In B and C they are too small to be considered significant.

The trees in D were slightly larger than those in B and in C up to the end of the 1925 season. Since then the trees in B and C have been progressively larger than those in D. The differences between B and D, and between C and D, were significant in 1931 and 1932.

The rate of growth of trees in all plots was influenced by factors other than irrigation. These other factors, however, seemed to affect all growth

in about the same way. In 1925, for example, a heavy infestation of red spiders appreciably decreased the growth rate of all the trees. In 1929 the rate was increased because a spring frost destroyed most of the crop. In 1930, when the crop was very heavy, the rate was appreciably decreased.

In general, the unirrigated trees resembled prune trees grown in districts with comparable rainfall and soil conditions where irrigation is

Fig. 11.—A typical prune tree in treatment D; February 1, 1933.

not practiced. They seemed to have fewer small branches (figs. 10 and 11) and fewer leaves than the irrigated trees. In summer they looked like healthy trees with a rather scant foliage. The trees in treatments B and C appeared, in general, similar to those of A. The growth of new shoots in D was noticeably less than in A. In all treatments, the trees blossomed and started growth at approximately the same time each year. No winter killing of twigs was observed, even when a minimum temperature of 10° F was reached.

Yields of the Prune Trees.—In 1923 the trees bore the first crop that warranted harvesting. In the next three years the yields were light and

irregular. There also seemed to be a tendency toward alternate bearing, the yields being lighter in 1924 and 1926 than in 1923 and 1925. The first moderate crop, produced in 1927, was followed by a light crop in 1928. In 1929, when a spring frost injured the blossoms, the yield was exceptionally light, except in one corner of the orchard. The crop in 1930 was extremely large, averaging from 16 tons of fresh fruit to the acre in treatment A, to 8 tons in D. The next year, 1931, the yield was light; in 1932, moderate. The average yield per tree arranged by treatments will be found in table 8, and the cumulative yields in table 9.

TABLE 8

AVERAGE YIELDS OF FRESH PRUNES PER TREE ARRANGED BY TREATMENTS

Year	Treatment A	Treatment B	Treatment C	Treatment D
	pounds	*pounds*	*pounds*	*pounds*
1923	53.1± 3.9	58.7± 4 0	51.1± 3.9	62.6 ± 3.9
1924	15.6± 3.7	13.5± 1.9	8.6± 1.4	7.9 ± 0.7
1925	42.3± 6.6	8.2± 1.4	52.7± 6.8	57.6 ± 3.9
1926	41.0±10.6	13.4± 3.1	13.5± 2.7	4.6 ± 0.8
1927	284.2± 6.2	272.3±10.1	301.2±11.1	255.2*± 8.9
1928	120.3±18.8	86.6±11.5	91.9± 9.8	76.4*± 9.9
1929	22.3± 7.3	10.8± 2.0	11.9± 3.6	39.6*± 9.1
1930	505.0± 9.4	460.2±15.4	373.2±10.2	284.6*±14.1
1931	15.0± 3.4	26.3± 2.9	14.9± 1.3	15.1*± 1.1
1932	225.2±13.9	220.3±12.2	217.4± 9.7	157.2*± 7.1
Average 1927-1932	195.3±15.5	179.4±14.4	168.4±12.6	138.0 ± 7.5

* Average of 19 trees. Tree 11, row 14, was omitted because of crown gall.

TABLE 9

AVERAGE CUMULATIVE YIELDS OF PRUNES

Year	Treatment A	Treatment B	Treatment C	Treatment D*
	pounds	*pounds*	*pounds*	*pounds*
1927	284.2± 6.2	272.3±10.1	301.2±11.1	255.2± 8.9
1927-1928	404.5±19.8	358.9±15.3	393.1±14.8	333.9±13.3
1927-1929	426.8±21.1	369.7±15.4	405.0±15.2	373.5±16.1
1927-1930	931.8±23.1	829.9±21.8	778.2±18.3	660.8±21.4
1927-1931	946.8±23.3	856.2±22.0	793.1±18.4	675.7±21.4
1927-1932	1172.0±27.1	1076.5±25.1	1010.5±20.8	832.9±22.6

* Average of 19 trees. Tree 11, row 14, was omitted because of crown gall.

The yields for the first four years were small, probably because of tree size, and irregular, the yields from treatment D being larger than those from A in two years out of the first four, and the yields from B much smaller than those from the other three treatments in one year of the four. Because of these irregularities and, because the size of the trees prevented the expected soil-moisture conditions from being obtained in all treatments, the yields of the first four years are considered separately in judging the effect of soil moisture on yields.

The average annual yields of treatment A were larger than those of B from 1927 to 1932 inclusive, except in 1931. During these years the permanent wilting percentage in the top 6 feet in B was reached about the middle of August except in 1931, when it was reached in September. These differences in yields, however, are not statistically significant.

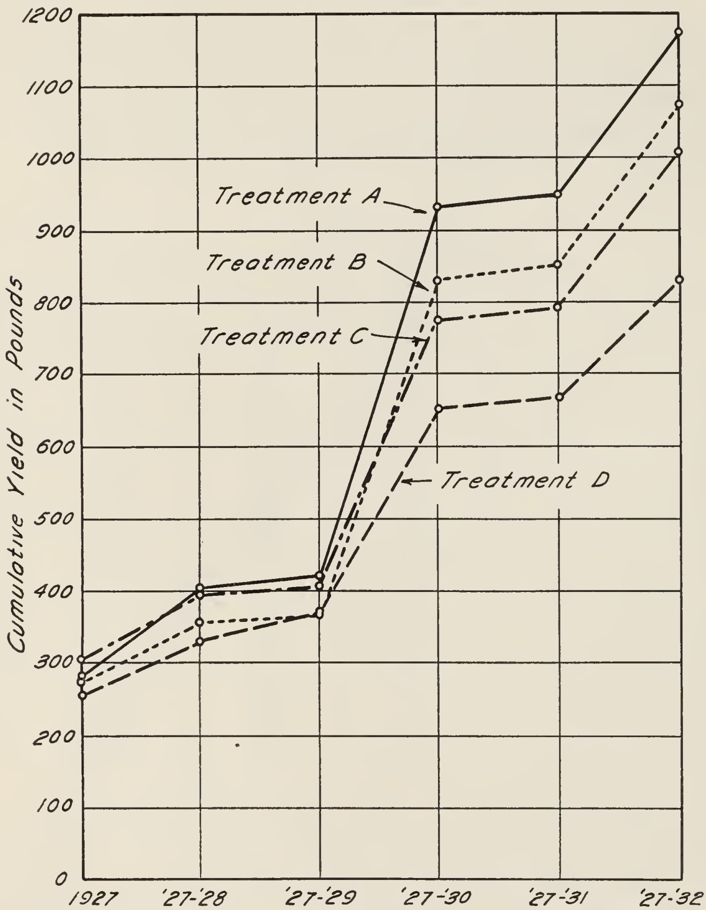

Fig. 12.—Average cumulative yields from 1927 to 1932, inclusive.

The yields of treatment A were larger than those of C, except in 1927; but the differences were statistically significant only in 1930, the first year in which the soil moisture in C reached the permanent wilting percentage in the top 6 feet and remained there for a considerable period.

The yields from treatment A were larger than those from D except in 1929, when the latter were affected less by the frost of that year than those of A; and in 1931, when the crop was very light because of the

large yield in 1930. The differences were statistically significant in 1930 and in 1932. The soil moisture in D was reduced to the permanent wilting percentage by about July 15 except in 1927, when it was reached a week or two later.

The yields from treatment C were larger than those from B in 1927, 1928, and 1929, but were smaller in the following three years. Statistically significant differences were obtained in 1930 and 1931. The yields from B were larger than those from D, except in 1929, the differences being statistically significant during the last three years. The yields from D were larger than those from C during 1929 and 1931; but smaller the other years, and significantly so in 1927, 1930, and 1932.

TABLE 10

AVERAGE DIAMETERS OF FRENCH PRUNES, 1932

Date	Treatment A	Treatment B	Treatment C	Treatment D
	cm.	*cm.*	*cm.*	*cm.*
April 29	1.24	1.25	1.24	1.25
May 5	1.37	1.37	1.36	1.41
May 13	1.56	1.53	1.51	1.59
May 20	1.73	1.70	1.70	1.78
May 26	1.80	1.77	1.77	1.86
June 3	1.92	1.88	1.88	1.97
June 10	2.04	2.00	1.99	2.09
June 17	2.15	2.08	2.09	2.20
June 24	2.33	2.25	2.21	2.34
July 1	2.53	2.46	2.35	2.48
July 8	2.70	2.62	2.47	2.59
July 15	......	2.79	......	2.68
July 22	2.95	2.87	2.66	2.70
July 29	3.04	2.92	2.72	2.73
August 5	3.06	2.94	2.75	2.75
August 12	......	2.96	......	2.78
August 19	3.06	2.94	2.79	2.78
August 26	2.95	2.81	2.69	2.64

The cumulative yields from 1927 to 1932, inclusive, obtained by adding the successive average yields together, are shown in table 9 and in figure 12. Those from A were larger than those from B, but significantly larger only in one case. In 1927 the yield from C was larger than that from A; but thereafter the cumulative yields from A were larger than those from C, and significantly so during the last three years. The yields from A were significantly larger than those from D for four years out of the last six, and were nearly so in 1927. The frost in 1929 probably explains the lack of a decisive difference in the cumulative yields of these two treatments that year.

The cumulative yields from treatments B and C show that the latter were larger from 1927 to 1929 inclusive, and smaller the other three

years. The difference between these two treatments, though not significant, apparently increased slightly from 1930 to 1932, inclusive. Except in the frost year, 1929, the cumulative yields from B were larger than those from D—significantly so the last three years. Those from C were significantly larger than those from D, or nearly so, except in 1929.

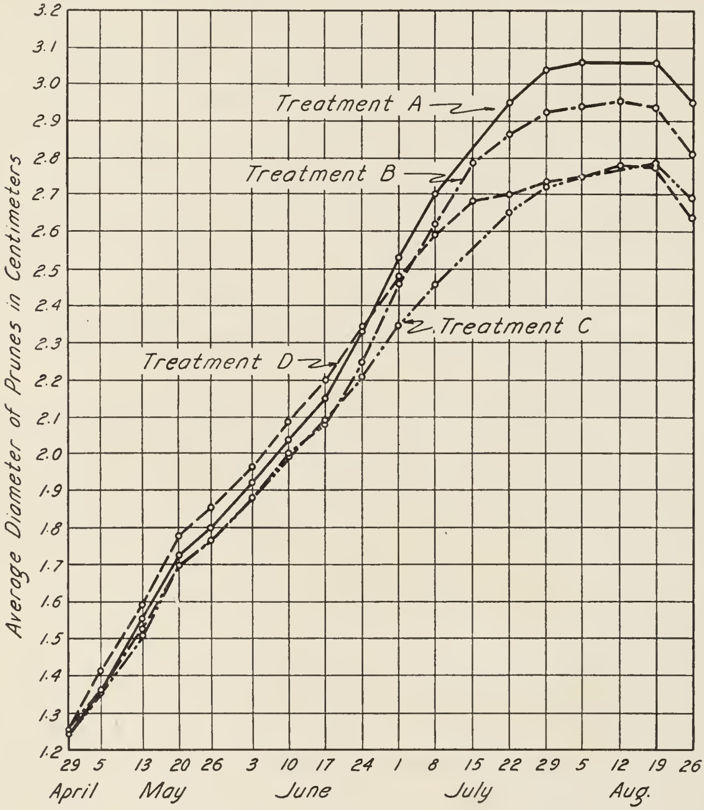

Fig. 13.—Growth of the prunes in 1932.

Rate of Growth of the Fruit.—In 1932, the tenth year of the experiment, the growth of fruit was measured at weekly intervals during the months of May, June, July, and August. Sixty fruits in each of treatments A, B, and C, and 120 in D were first marked with a small spot of india ink approximately 90 degrees from the suture and then measured with calipers.

The average sizes of these fruits are shown in table 10 and in figure 13. As the curves show, the fruit in all plots was about the same size on April 29. Thereafter, until June 24, the fruit was slightly larger in D

than in the other treatments. In general, the fruit reached full size from two to four weeks before harvest. The dates on which the fruit proved significantly smaller in some treatments than in others correspond closely to the dates when the available soil moisture in the former treatments was exhausted.

Significant differences in average fruit sizes were obtained between treatments A and B on and after July 29; between A and C, on and after June 24; between A and D, on and after July 8. The probable errors for the size measurements in A, B, and C, in almost every case were $\pm$ 0.02; those for D, $\pm$ 0.01. Differences of 0.09 centimeter or more between A and B, A and C, or B and C are significant by odds of 30 or more to 1. Differences of 0.07 centimeter or more between D and any one of the other treatments are also significant. The fruit in B was significantly larger than that in C on and after July 1. It was larger than that in D on and after July 15, although the latter had been significantly larger from May 20 to June 24. Likewise, the fruit was significantly larger in D than in C from May 13 to July 8, after which they were nearly the same size for several weeks.

As shown by the record for 1932 (fig. 8), the available soil moisture in the upper six feet in treatment C reached the permanent wilting percentage about June 16. Approximately a week later, the fruit in C was significantly smaller than that in A; about two weeks later, significantly smaller than that in B. The latter was significantly smaller than that in A on July 29. On the next sampling date, August 9, the soil of treatment B was reduced to the permanent wilting percentage. Probably, because this condition occurred in D two or three weeks later than in C, the fruit in D did not become significantly smaller than that in A and B until about two weeks later than did the fruit in C. As the curves show, the rate of growth in C was appreciably decreased during the latter part of June, when this treatment lacked readily available water; and, even when irrigated again, the fruit did not reach the size of that in treatments A and B. The measurements a few days before harvesting showed a marked decrease in size, probably because of a partial drying on the trees.

Sizes of the Dried Fruit.—During the last three years of the experiment, the dried fruit was run through a mechanical sizer having six screens, with openings of 28/32, 30/32, 32/32, 34/32, 36/32, and 38/32 inches. Table 11 gives the results as percentage of the total dried crop from each treatment. Table 8, in which the annual yields are compared with the distribution of sizes, shows how the total fruit produced influences the average size of the individual fruits. Thus in 1930, when the crop was heavy, nearly all the fruit was small; while in 1931, with a

light crop, the individual fruits were usually large. In 1932, with an average crop, the percentage of large prunes exceeded that of 1930, but was smaller than in 1931.

TABLE 11

Sizes of Dried Prunes Expressed as Percentage of the Dry Yield and as the Average Number of Prunes to the Pound

Treatment	Screen sizes in inches						Over end of sizer	Average number prunes per pound
	28/32	30/32	32/32	34/32	36/32	38/32		
				1930				
A	62.7	26.4	7.8	2.7	0.5	0	0	131.2
B	59.4	23.3	11.8	4.6	0.9	0	0	106.3
C	65.2	24.9	7.6	2.2	0.1	0	0	139 8
D	76.2	18.2	4.4	1.2	0.0	0	0	143.6
				1931				
A	0.4	0.9	2.2	5.4	10.3	17.4	63.4	44.3
B	0.5	2.2	5.8	10.0	15.6	22.2	43.7	47.6
C	1.1	1.7	3.7	9.5	17.7	22.1	44.2	43.4
D	1.7	4.6	9.8	15.5	21.0	20.9	26.5	48.8
				1932				
A	27.5	22.5	18.7	14.3	9.4	4.4	3.2	86.6
B	25.3	25.1	21.7	15.0	8.2	3.3	1.4	88.7
C	33.1	24.8	19.8	13.1	6.1	2.1	1.1	92.5
D	41.3	30.0	16.8	7.7	3.0	0.9	0.3	97.4

The smallest fruits were produced in D, the unirrigated treatment. The differences in dried-fruit size in A and B are small except in 1930, when B produced larger prunes. The average size produced by C in 1930 and in 1932 was slightly smaller than that from both A and B. In 1931 this situation was reversed, the fruit from C being slightly larger than that from A and B, although the soil-moisture conditions in C were similar during all three years. On the average the fruit of the experimental orchard is smaller than that from most other prune-growing sections.

Ratios of Fresh to Dry Weight of Fruit.—The drying ratios, or ratios of fresh to dry weight of fruit, for the last six years of the experiment are given in table 12. The results in 1927, 1928, and 1929 were obtained by sun-drying; those in 1930, 1931, and 1932, by dehydration. Those for 1928 and the last three years were corrected to a uniform moisture content of 20 per cent. As the fruit from each tree could not well be dried separately, that from each plot was dried as a unit. As the data show, the drying ratios from any one treatment are not consistently higher or

lower than those from any other. In some cases the differences from one year to another are greater than those between treatments. The latter are so slight as to have little or no significance; however, the average drying ratio for six years for treatment A was 2.7 to 1; for B, 2.7 to 1; for C, 2.7 to 1; and for D, 2.6 to 1. The variations in drying ratios from one year to another may result from the method of harvesting. The fruit is allowed to fall or is shaken to the ground as in commercial practice.

TABLE 12

RATIO OF FRESH TO DRY WEIGHT OF PRUNES

Year	Treatment A	Treatment B	Treatment C	Treatment D
1927*	3.1	3.1	3.1	3.2
1928	2.5	2.5	2.3	2.3
1929*	2.0	2.3	2.0	2.0
1930	3.3	3.0	2.9	3.0
1931	2.5	......	2.7	2.3
1932	2.9	2.8	3.0	2.6

* Not calculated to a uniform moisture content. The other drying ratios are calculated to 20 per cent moisture.

It may lie on the ground for a longer period in certain years than in others. The fruit from any one treatment, however, did not ripen and drop earlier than that from any other. The partial drying before the crop can be picked up and weighed undoubtedly influences the drying ratio. The slight differences in drying ratios in A, B, C, and D are not explained by the irrigation treatment.

TABLE 13

SUGAR AND ACID CONTENTS OF FRESH PRUNES AND SPECIFIC GRAVITIES OF DRIED PRUNES ARRANGED BY TREATMENTS

Year	Per cent total sugar on fresh-weight basis				Per cent acid as malic on fresh-weight basis				Specific gravity			
	A	B	C	D	A	B	C	D	A	B	C	D
1930	11.86	11.67	12.00	11.63	....	....	....	....	1.25	1.25	1.21	1.20
1931	13.80	13.84	14.26	13.71	0.81	0.85	0.89	0.88	1.19	1.17	1.18	1.19
1932	11.78	12.06	11.50	11.60	0.67	0.69	0.66	0.69	1.07	1.10	1.09	1.10

Sugar and Acid Contents and Specific Gravities.—The total sugar and acid contents, expressed as percentages of the fresh weight of fruit, and the specific gravities are given in table 13. The sugar and acid contents were obtained from composite samples of 125 fruits from each plot; the sugar analyses, from material preserved in alcohol by the Schaefer-Hartmann method. Although the differences in sugar contents were small, the percentage of sugar in D was slightly lower than that in

A in every case, and slightly lower than that in either B or C in every case except one. No consistent differences in sugar contents of fresh fruit appeared between A and either B or C. All treatments contained more sugar in 1931 than in either 1930 or 1932. During the two years when acidity tests were made, the acid contents of the fruit were substantially the same for all treatments each year.

After curing, the dried prunes were separated into seven sizes. Samples of each size from all plots were used in specific gravity determinations, made by the method of Nichols and Reed,[3] who have shown that such determinations may be used as a measure of quality. The specific gravities given in table 13 are the averages of those of the seven sizes; they differ so slightly in any one year that they appear unaffected by the irrigation treatment. On the average, however, they were slightly higher in 1930 than in the other two years. Observation of the quality by cutting 300–400 prunes from each plot showed that the flesh was lighter colored and the gas pockets were fewer in 1930 than in either 1931 or 1932. The yield record shows a heavy crop for 1930, a light crop for 1931, and a moderate crop for 1932. The specific gravity, too, was higher and the observed flesh color better when the crop was heavy (1930) than when it was very light (1931) or moderate (1932). As these data show, the specific gravity of the dried product was not influenced by the irrigation treatment.

DISCUSSION

Soil Moisture and Growth of the Trees.—The differences in growth of the trees shown in figure 9 agree with soil-moisture conditions. The trees in treatment A were larger than those in D in 1924 and 1925, and have clearly diverged from them since the end of the 1926 season, as shown in figure 9. The differences between A and B and between A and C have, in general, been increasing, but are not statistically significant, although those between A and C are nearly so in 1931 and 1932. In size, the trees of treatments B and C do not differ significantly, whereas those of D have clearly been diverging from both of them. Evidently growth was retarded by allowing the trees to reduce the soil moisture to about the permanent wilting percentage during certain parts of the growing season and to remain wilted for a considerable length of time.

By the end of 1932, although B was smaller than A, the difference was not significant. This fact is surprising, when one considers the relatively long period each year since 1927 that B was without readily available water in the top six feet. A possible explanation may be that both these treatments had readily available moisture (fig. 8) in the spring and early summer, when the circumference increases rapidly. After the

spring growth, the slower increase during the laying down of the summer wood in the annual rings was evidently not greatly influenced by the different soil-moisture conditions in the two treatments. Inasmuch as D reached the permanent wilting percentage two or three weeks before B, this dry period may have come early enough to influence the circumference increase during the rapid spring growth. With the trees in C, furthermore, since the dry period occurred earlier than in B, even though it was relatively short, it may have checked the rapid spring growth; and the late summer irrigations did not increase the growth sufficiently to compensate. Readily available water below six feet is relatively unimportant, as discussed later.

The importance of maintaining readily available moisture in June and early July is shown by comparing the growth of trees in A, B, and C. The relatively short period in midsummer, when C lacked readily available moisture, checked this growth as effectively as did a much longer period later in the season in B. Both the soil-moisture records and the tree measurements indicate that the permanent wilting percentage is a critical soil-moisture condition, and show that lack of readily available water affects growth more in midsummer than in late summer.

Though periods of drought at various times during the season influenced the comparative differences in tree size, other factors were important. For example, the rate of growth was decreased in all plots, first in 1925, by a severe red-spider infestation, and again in 1930, by a heavy crop. On the other hand, the trees grew a little faster than usual in 1929, when a late frost killed nearly all blossoms.

Considering the severity of the treatment, the trees in the unirrigated plots were remarkably thrifty after the first eight or nine years of the experiment. Some of the upper branches, however, died back two to three feet in 1932. According to these results, prune trees on a fertile soil can withstand a lack of readily available moisture for a relatively long period each season and still produce fair crops for a number of years.

On the other hand, readily available moisture maintained in the fall did not cause growth that was susceptible to injury by the temperatures ordinarily prevailing in the prune-growing sections of California. Whether irrigated in the fall or allowed to enter the dormant period in a wilted condition, the trees showed no evidence of injury by low temperatures during the winter months.

Soil Moisture and Yields.—As previously mentioned, the trees began to bear the year the differential irrigation treatments were started. For the first four years the yields were small and irregular, possibly because of the age of the trees. In addition, because of tree size, the desired soil-

moisture conditions were not obtained in all treatments. The yields for the first four years, therefore, are considered separately in the following discussion.

Apparently, the reason that the yields did not follow the same general trend during the first four years as during the last six was that the soil moisture in some treatments was not reduced to the permanent wilting percentage early enough in the season to affect the yields. The general results with growth and yields of prune trees agree with other experiments[1,2,4] in which differences were not obtained until the soil moisture neared the permanent wilting percentage.

The pronounced differences in soil-moisture conditions after 1926 would lead one to expect larger differences in yield than were actually obtained. The annual records illustrate the difficulties encountered in interpreting yield data from single years. Obviously, the frost in 1929 and the heavy crop of 1930 tended to mask any effects of the irrigation; but even with these years excluded, annual yields differed significantly in less than half the possible cases. These results are rather surprising because treatments B and D lacked readily available water for relatively long periods as early as 1927. The average annual yields, however, indicate that A produced the largest yields, followed by B, C, and D in order. Only the differences between A and D are statistically significant. Evidently, therefore, prune trees at Davis may lack readily available water for considerable periods, especially in late summer, without materially lessening the yields.

The grower, though interested in yields for any one year or in the average yield for a number of years, may also be concerned with the total yield over a number of years. Table 9 shows that on the average the trees in treatment A in the years from 1927 to 1932, inclusive, produced 1,172 pounds of dried fruit each; those in B, 1,076 pounds; those in C, 1,010 pounds; and those in D, 828 pounds.

According to these results, shown graphically in figure 11, the irrigation treatments have brought about increasing differences in cumulative yields. These differences, however, have not always increased regularly. In comparing severity of treatments under Davis conditions, for example, one notes that a period of two to three weeks without readily available moisture in the soil during one part of the season may affect the trees and yields as decisively as a longer period at another time. Treatment C, for example, was dry for a relatively short time each year during late June and early July. Despite favorable soil-moisture conditions later in the season, the cumulative yields from this treatment were slightly, although not significantly, smaller than those from B, which was dry from about the middle of August until the fall rains, several

months later. The trees in D were subjected to approximately the same soil-moisture conditions as those in C in late June and early July and, in addition, remained dry until the fall rains (usually in late October or November).

As shown by the records, not only the length of time the soil lacks readily available moisture, but also the season when the soil moisture nears the permanent wilting percentage, must be considered in interpreting growth and yield data. The records for treatments B and C illustrate this point, because C lacked readily available water for a comparatively short period in midsummer, B for a much longer period beginning about the middle of August. If length of time is considered without regard to season, the order of growth and yields should be A, C, B, and D; but this was not the case. If, however, the two treatments reached the permanent wilting percentage at the same time, the one that remained there the longer may be affected the more severely.

Effects of Fall Irrigation on Growth and Yields.—The fact that the soil in some treatments was dry for considerable periods in the fall without greatly affecting the growth or yields agrees with observed results in many unirrigated commercial prune orchards throughout California. The trees in these orchards, though smaller and less productive than those in other irrigated orchards in the same region, yield fairly satisfactory crops. Usually, the trees are growing on soils of relatively high water-holding capacity and are of such a size that the permanent wilting percentage is not reached until relatively late in the season. Fairly satisfactory crops, no doubt, are produced in many commercial orchards where the soil moisture remains close to the permanent wilting percentage for relatively long periods in the latter part of the season of each year.

The fact that neither the rate of growth of fruit nor the general appearance of the trees were affected until the readily available moisture was exhausted, indicates that the moisture requirements of prune trees are fulfilled if the soil moisture is maintained above the permanent wilting percentage. Even if, however, the trees are allowed to exhaust the readily available moisture after about the middle of August, as in treatment B, the yields may not be materially affected. After ten years of such treatment, the yields of B were only slightly smaller than those of A, even though the cross-section areas of the trunks are becoming progressively larger in A than in B. The difference in tree size in the two treatments may later become sufficient to affect the yields more than during the past ten years. Judging, however, from results thus far, the omission of a fall irrigation was not followed by such serious consequences as might have been expected.

Soil Moisture and Growth of the Fruit.—The lack of readily available soil moisture was reflected, however, in the growth of the fruit. In 1932, the fruit in treatments C and D grew more slowly when the soil moisture was close to the permanent wilting percentage. The fruit in B grew more slowly than that in A toward the end of the season, when the readily available water in B was exhausted.

Treatment C lacked readily available soil moisture for only about three weeks during the last part of June and the first part of July, but the effect was very marked. Although in the treatment irrigation was applied shortly after this dry period, the fruit remained smaller than that of A and B. These results are similar to those obtained with peaches.(1)

The fruits on the irrigated and nonirrigated treatments show interesting differences in the rates of growth. At the beginning of the season, after ten years of differential irrigation, they were all approximately equal in size and in rate of growth until the soil moisture in certain treatments was reduced to about the permanent wilting percentage. Evidently the rate of growth of prunes is affected by soil moisture only when the readily available water in the top 6 feet is exhausted, and can be detected only when fruits on treatments having no readily available soil moisture are measured and compared with those from treatments having such moisture. During the early part of the season, furthermore, when water was still readily available, growth of fruit was not affected by the soil-moisture conditions of the previous year. In other words, the previous summer's irrigation treatment had no "holdover" effect on the fruit.

In comparing growth and soil-moisture extraction curves, one sees a decrease in growth of the fruit corresponding closely to the time when the readily available soil moisture is exhausted. On the other hand, apparently, no increase results from adding water to those treatments in which the moisture content is above the permanent wilting percentage. The belief that by irrigating shortly before harvest, one can make the fruit absorb extra water and thus markedly increase in size, is not borne out by these experiments, nor by those with peaches.(1)

Soil Moisture and Size of the Fruit.—Since prunes are sold on the basis of size, the grower wishes the trees to produce, as far as possible, fruits of desirable size. With peaches, plums, apples, and apricots, hand thinning reduces the crop so that the fruit remaining will grow to marketable size. French prunes, however, are not thinned and consequently, in years of large crops, may run to small sizes. The question naturally arises as to the effect of irrigation on size. Obviously, the average size of fruit is greatly influenced by the amount on a tree, so that it may be

small one year and large the next. The only consistent effect, apparently, of irrigation upon the size of individual fruits is that the unirrigated trees, for the past three years, have produced the greatest percentage of small-sized dried prunes.

In 1932 the average sizes of the dried fruits follow the same order as those of the measured fresh fruits, which show significant differences between certain treatments. The proportion of the various sizes from a given treatment, together with the total yields, may affect the returns to the grower. For example, using the yields and prices received in 1932, although the average yields per tree in treatments A, B, and C were nearly equal, the gross returns from A were $68.40 an acre; from B, $67.92; from C, $58.44. The relatively low gross returns from C were largely because of a high proportion of small-sized fruit in that treatment. The gross returns from D, with low yields and small-sized fruit, were only $41.58.

Since it required extreme differences in soil-moisture conditions to produce relatively small differences in size of prunes, it is reasonable to expect that fluctuations from the field capacity to about the permanent wilting percentage will have no effect on the size.

Drying Ratios of Fruit.—French prunes are seldom sold fresh, but are generally dried or dehydrated. According to popular opinion, irrigated fruit contains more water than unirrigated, so that the drying ratio, or the ratio of fresh to dry weight should be greater for the irrigated fruit than the unirrigated. During the last six years of the experiment, however, the results, despite considerable variation in the drying ratio from year to year, show no marked differences between treatments. In other words, irrigation did not materially change the drying ratios. Furthermore, none of the irrigation treatments appeared to induce cracking of the fruit. Considering the severe conditions to which some trees were subjected, one might expect greater differences. Similar results were secured with Muir peaches[1] and with Thompson Seedless grapes.[2]

Soil Moisture and Quality of the Fruit.—The sugar and acid contents during the last three years of the experiment likewise show no consistent differences between treatments. Nichols and Reed,[3] as previously indicated, concluded that the specific gravity of prunes is a measure of quality. In the present experiments it showed only small differences between treatments. Evidently where readily available moisture in the top 6 feet of soil is not exhausted until midsummer, irrigation had very little effect on quality, as measured either by the sugar content of the fresh fruit or by the specific gravity of the dried product.

In the last six years of the experiment, when the soil was wet to a depth of 6 feet at the beginning of each growing season, the permanent wilting percentage was reached about the same time in the 0 to 3 and the 3 to 6-foot depths. These results, however, might not have been obtained if the moisture properties of the first and the second 3 feet of soil had differed more markedly than in this orchard. As the results show, the prune trees were influenced by the soil moisture in the upper 6 feet; and the presence of available water below this depth did not prevent wilting, even though the extraction curves indicate the presence of some roots at this depth.

Extraction of Soil Moisture by the Trees.—Records show that the soil moisture in the 6 to 9 and 9 to 12-foot depths was generally higher in C than in B during most of the growing season. The rainfall on the average did not wet the soil more than about 6 feet in the B treatment, but penetrated more deeply in C, because of moisture remaining from irrigation during the previous fall. Treatment C had readily available water below 6 feet at all times; but B lacked it, in the 6 to 9-foot depths, at certain periods, as shown by the soil-moisture records of the last six years of the experiment. In treatment C, despite readily available moisture present below 6 feet, the growth and yields of the trees were smaller than in B, though not significantly so. These results indicate that yields and growth of trees are principally influenced by the soil-moisture condition in the top 6 feet and that the moisture below this depth is relatively unimportant under Davis conditions. Evidently, wetting the soil below 6 feet by winter irrigation is unnecessary. This conclusion agrees with previous studies of peaches and prunes.(1, 4) In years of deficient rainfall, however, winter irrigation may be desirable to wet the soil to a depth of 6 feet, or to the full depth where there is an impervious layer less than 6 feet below the surface.

The soil-moisture curves showing the rate of extraction by the trees (figs. 5, 6, 7, and 8) are essentially straight lines, indicating a pronounced change in direction when the soil moisture is reduced to about the permanent wilting percentage. The extraction of moisture, after reduction to the permanent wilting percentage, does not entirely cease, as is shown in the curves. The uniform rate of extraction is especially evident early in the season. The curves sometimes descend more rapidly immediately after irrigation than later, because the samples were taken before the soil had drained to its field capacity. The substantially uniform extraction rate between the field capacity and the permanent wilting percentage indicates that prune trees can obtain water with equal facility from the field capacity to about the permanent wilting percentage. Previous experiments with prunes, peaches, and grapes

gave similar results.[4,1,2] Since the needs of the tree seem to be supplied by soil moisture between the field capacity and the permanent wilting percentage, additional water, applied while the moisture contents are between these limits, will presumably not influence the responses of the trees. In practice, of course, one may have to begin irrigation before the readily available water is exhausted, in order to cover the orchard before any tree shows evidence of wilting.

Mature prune trees at Davis, starting the season with the upper 6 feet of soil wet to the field capacity, generally reduced the moisture in this depth to about the permanent wilting percentage during the period from the middle of June to the first part of July. Ordinarily, according to these results, mature prune trees on soils essentially similar to those at Davis, with similar rainfall, need not receive the first irrigation earlier than about June 15.

The soil-moisture curves show the approximate length of time that moisture is available after each irrigation, at Davis. Ordinarily, in midsummer, an irrigation that wets the soil to a depth of 6 feet is exhausted in about six weeks. To maintain the supply of readily available moisture, as previously stated, the first irrigation is necessary between the middle and the last of June. A second irrigation is required about August 1; and a third about September 15 or shortly after harvesting. When the readily available soil moisture was exhausted before water was applied, about 8 acre-inches of water per acre, exclusive of losses, was required to wet the soil to a depth of 6 feet at each irrigation. Because of soil variations, some parts of the orchard required less, others more. When the available water supply was not yet exhausted, less than 8 acre-inches per acre would wet the soil to a depth of 6 feet.

The average seasonal application of water to treatment A during the last five years was 25 acre-inches per acre. By using this amount, together with rainfall, a supply of continuously available moisture was maintained throughout the year; and less would probably have sufficed, since sometimes the soil was moistened to a depth greater than 6 feet, and at times water was applied before the readily available supply was exhausted.

Constancy of the Permanent Wilting Percentage.—The soil-moisture contents in the top 6 feet, at which there was a marked decrease in the rate of extraction of moisture, which corresponds to the permanent wilting percentage, were approximately equal each year. This fact emphasizes the constancy of the permanent wilting percentage. Trees allowed to wilt for portions of the growing season during each of the last five years of the experiment, nevertheless did not lower the permanent wilting percentage in spite of these repeated wiltings, and were, from this

standpoint, no more drought resistant at the end of this period than at the beginning. Prune trees, as previously pointed out, are drought resistant in being able to produce fair crops despite long periods of drought during the last part of the growing season; but this ability seems to be inherent in the trees, and not acquired during the experiment.

The results of this ten-year study indicate how readily available moisture may be maintained during the growing season without undue waste and often with a considerable saving in costs.

Outline of Economical Irrigation Practice for Prune Orchards.—The following suggestions on prune trees will serve, with some modifications, for irrigation practice in most districts in California where prunes are grown. As previously pointed out, mature prune trees at Davis usually exhaust the readily available soil moisture in the top 6 feet between the middle of June and the first week in July. Inasmuch as the 0 to 3 and the 3 to 6-foot depths of soil at Davis reached the permanent wilting percentage at approximately the same time, with a similar soil, common pigweeds or other broad-leaved weeds, though shallower-rooted than the trees, will indicate when the readily available moisture is exhausted.

Another reason for using a few such broad-leaved weeds as indicator plants is that they show wilting more distinctly than the prune trees: ordinarily their leaves droop temporarily during the afternoon when readily available moisture is nearly exhausted. Of course trees are likewise affected, but if this soil-moisture condition is not allowed to persist for more than a few days, the effects are not serious. When the leaves do not recover turgidity during the night, but remain wilted, the soil moisture is reduced to about the permanent wilting percentage.

Because the moisture properties of soil are variable, nearly all orchards have some areas from which the readily available water is exhausted soonest. By noting the first signs of drooping in the weeds in these areas, the grower still has a few days in which to prepare for irrigation. Where only small heads of water are available, however, some trees may be decidedly affected before they are irrigated. By observing the indicator weeds, for a season or two, one can generally irrigate so as to maintain readily available moisture at least throughout a major portion of the orchard.

Irrigation before the readily available moisture is exhausted replenishes the supply sooner than necessary. Of course, if this is done, less water is needed to wet the soil to a depth of 6 feet; but, during the season more frequent irrigations are necessary, with more waste than if watering were delayed until the top 6 feet was almost dry.

Though the trees evidently are not affected by irrigation before the readily available moisture is exhausted, they may be injured if the soil

becomes water-logged and its oxygen supply is reduced by too frequent irrigations. Furthermore, leaching may take place if the applications of water are too frequent or too large.

The readily available soil moisture from the first irrigation, under Davis conditions, will usually be exhausted in about six weeks, necessitating a second irrigation between the first and the middle of August. If the grower wishes to maintain readily available moisture until late fall, a third irrigation is necessary, in September.

At Davis about 8 acre-inches per acre would moisten 6 feet of soil, when the readily available moisture was exhausted. As a matter of expediency, some growers apply only enough water to wet about 3 feet of soil in the fall. Probably, under climatic conditions similar to those at Davis, the total water required by mature prune trees would not be affected by the soil type. Soils holding comparatively little readily available water will require more frequent but smaller applications than those at Davis. On the other hand, soils retaining much readily available moisture may be irrigated less often, with more water at each application, than at Davis. The availability of soil moisture is discussed in a previous publication.[7]

Sometimes the grower must dispense with an irrigation. Which, then, may best be omitted? According to these experiments, a drought period of two or three weeks in midsummer reduced yields more than a much longer dry period in the fall, and indicated that the safest irrigation to omit is the last one.

SUMMARY

After four years of differential irrigation treatment, the trees in the continuously moist treatment averaged largest, those in the intermediate treatments next, and those in the unirrigated treatment smallest. This order was maintained throughout the remainder of the ten-year period. The differences were not always statistically significant.

The reason that differences were not apparent earlier in the experiment may be because the soil was not permeated with roots.

The growth and yields were affected as much by the lack of readily available moisture for a relatively short period in midsummer as for a longer period late in the growing season.

The growth of prune trees in all treatments was materially affected by the amount of crop produced and by severe red-spider infestation.

No winter injury was evidenced during the ten-year period, even by the trees irrigated late in the fall.

During the first five years of the experiment, no differences in yields could be attributed to the irrigation treatment.

After five years of differential irrigation treatment, the cumulative yields from the trees in the continuously moist treatment averaged largest; those from the intermediate treatments, next; and those from the unirrigated treatment, smallest. Likewise, the average annual yields followed in the same order.

Sizes of both fresh and dried prunes were not influenced by the amount of readily available moisture in the soil, but were affected by the lack of it during the growing period of the fruit.

Decisive differences in growth of trees, yields, and fruit size did not appear unless the soil moisture was reduced to about the permanent wilting percentage during the growing season, although significant differences were not always obtained even then.

Differences in specific gravities, sugar and acid contents, and drying ratios of French prunes from the different irrigation treatments were surprisingly small.

The initial size and rate of growth of prunes early in the growing season were essentially the same regardless of the irrigation treatment of the previous growing season.

Neither blossoming time nor the beginning of growth was affected by the irrigation treatment of the previous growing season.

French prunes ordinarily attained full size from three to four weeks before the usual harvest time.

Lack of readily available soil moisture during the fruit growing period seriously affected the growth rate of the fruit, which subsequently, even though the trees were irrigated later in the season, remained smaller than in the continuously moist treatment.

After the trees were about ten years old, the permanent wilting percentage in the 0 to 3 and the 3 to 6-foot depths was reached at about the same time, whenever the soil was wet to a depth of 6 feet at the beginning of the season or after an irrigation.

The permanent wilting percentages of each plot, indicated by the distinctly changed slope of the moisture extraction curves and also by the general appearance of the trees, agreed from year to year.

Though mature prune trees at Davis were usually affected when the soil moisture was reduced to about the permanent wilting percentage in the top 6 feet, readily available moisture below this depth did not keep them from wilting.

After ten years the unirrigated trees did not reduce the soil-moisture content at permanent wilting lower than at the beginning of the experiment. In this sense they were no more "drought resistant" at the end than at the beginning.

Mature prune trees at Davis exhausted the readily available soil moisture in the top 6 feet, in years of normal rainfall, some time between the middle of June and the first week in July. In midsummer, after an irrigation, they exhausted it in about six weeks.

The prune trees obtained moisture as readily near the permanent wilting percentage as to the field capacity.

The results obtained in these experiments indicate that applying water to a prune orchard shortly before the moisture content of the top 6 feet of soil is reduced to the permanent wilting percentage constitutes good irrigation practice.

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